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INSTRUCTION MANUAL FOR

AILTECH 32

PRECISION IF ATTENUATOR

[redacted]

REVISION B

AILTECH
A CUTLER-HAMMER COMPANY
CONTROL
CITY OF INDUSTRY, CA 91748

QUALITY ASSURANCE
STANDARDS, CALIBRATION, AND
MAINTENANCE LAB

INSTRUCTION MANUAL FOR

AILTECH 32
PRECISION IF ATTENUATOR

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A CUTLER-HAMMER COMPANY
CONTROL

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SECTION I
INTRODUCTION

The AILTECH 32 Precision IF Attenuator (Figure 1) is an attenuation standard designed for use at a fixed intermediate frequency. It may be used in the laboratory, in test instruments, or as part of a custom-built test system. The attenuation is continuously variable from 0 to 100 dB above the minimum insertion loss of the instrument.

FIGURE 1. AILTECH 32 PRECISION ATTENUATOR

SECTION II
SPECIFICATIONS

Five models of the AILTECH 32 Precision IF Attenuator are available (Model 3220 for 21.4-MHz operation, Model 3230 for 30-MHz operation, Model 3250 for 50-MHz operation, Model 3260 for 60-MHz operation and Model 3270 for 70-MHz operation). These models may also be obtained mounted on a standard rack panel (032-1), or housed in a walnut case (032-2). The outline and mounting dimensions for the Models 032-0 are given in Figure 2. The electrical specifications are given in Table 1.

TABLE I. ELECTRICAL SPECIFICATIONS

	Models				
	3220	3230	3250	3260	3270
Center frequency	21.4 MHz,	30 MHz,	50 MHz,	60 MHz,	70 MHz
Input and output impedance	50 ohms nominal				75 ohms nominal
Input and output SWR	1.2 maximum				
Input power	1 watt maximum				
Range, incremental	100 dB minimum				
Minimum insertion loss	18 dB nominal				
Error, maximum (dB)	0.005/10 + 0.03 + (0.03 (Note 1) (<<0.03 (Note 2)				

TABLE I. (Continued)

Resolution	0.01 dB/division
Connectors	TNC
Weight	2 pounds

Note 1: This error may occur when the attenuator reference is set for a digital dial reading of 0.00.

2: When the attenuator reference is set for a digital dial reading of 10.00 or larger, the error is negligible.

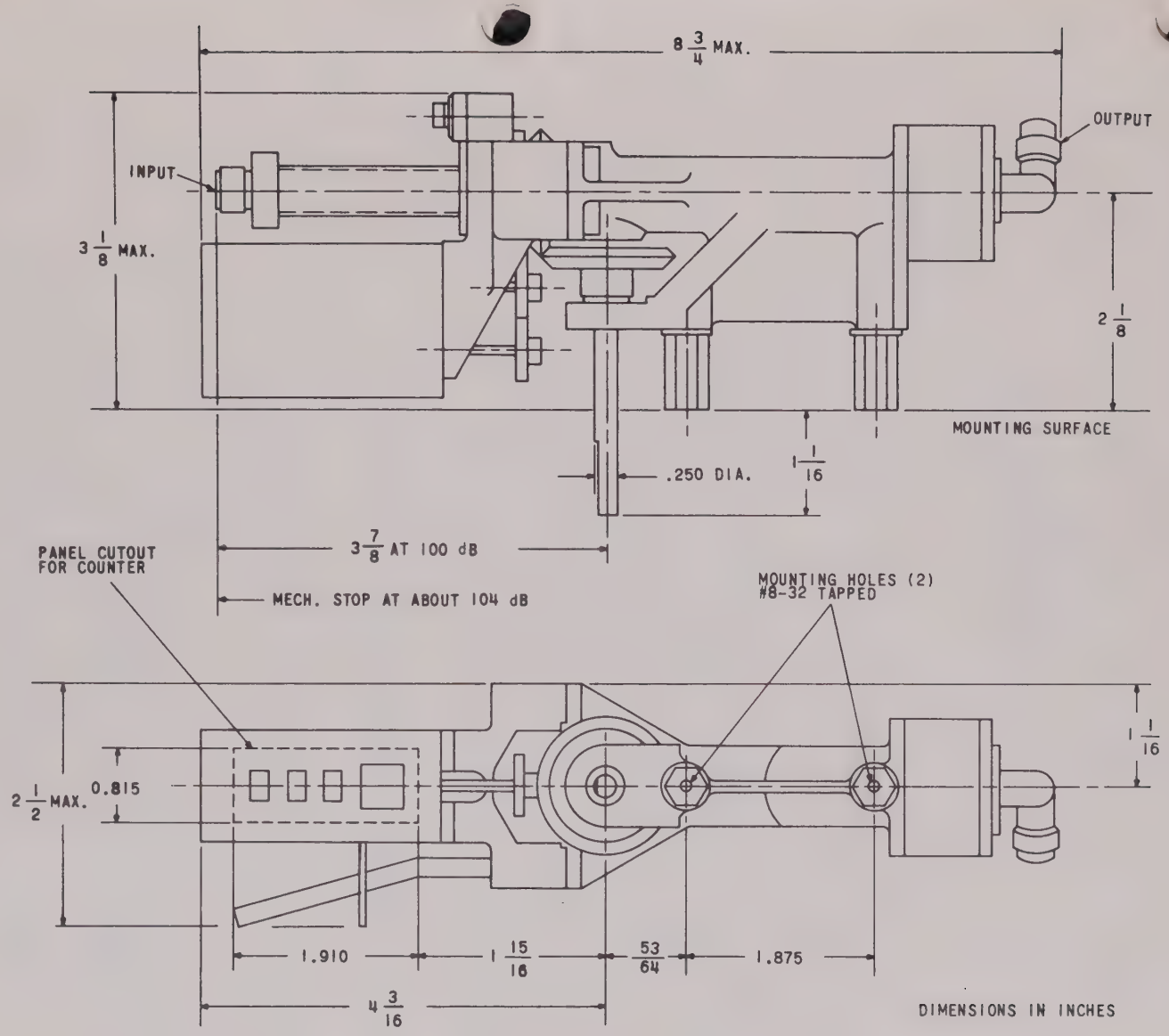

FIGURE 2. OUTLINE AND MOUNTING DIMENSIONS

SECTION III
OPERATING INSTRUCTIONS

A. INTRODUCTION

The counter indicates the attenuation in dB above the minimum insertion loss.

An increase in attenuation between the input and output ports is accomplished by rotating the control shaft in a counterclockwise direction. When an accurate indication of incremental attenuation is required, it is recommended that the control shaft be rotated in the same direction to obtain the reference and final attenuation settings. This minimizes backlash errors of typically 0.02 dB.

To ensure proper operation of the equipment, perform the following steps.

1. Connect the AILTECH 32 precision attenuator into the measurement system.
2. Rotate the attenuator knob counterclockwise from a 997.00 (below zero) reading to obtain an initial reference reading.
3. Adjust the AILTECH 32 attenuator to its final reference reading.
4. The attenuation change is the difference between the

two readings. In most cases, an initial reference reading of 0.00 is chosen. The attenuation difference would then be read directly off the digital indicator.

B. OPERATING PRECAUTIONS

To obtain maximum accuracy and performance using the attenuator, the following precautions should be observed:

1. Input power must be limited to 1 watt. Exceeding this level will permanently damage the attenuator. If desired, the output jack may be used as the input jack providing the input power is limited to one-third watt maximum.
2. In any installation where the attenuator is to be motor driven, proper gearing must be provided so that the control shaft is not driven faster than 150 rpm. Torque should be removed from the control shaft before it is driven to the mechanical stops.
3. Errors can be minimized by approaching the desired readings from a counterclockwise direction.

Inductive coupling is used at both the input and the output of the waveguide. At the design center frequency, the input and output impedances are purely resistive, appropriate capacitances being in series with the input inductance. At other frequencies, these impedances become partially reactive.

The magnitude and phase of these impedances are shown in Figure 3. These factors must be considered when using the attenuators at other than the design center frequency. An impedance mismatch will affect the insertion loss of the device under test.

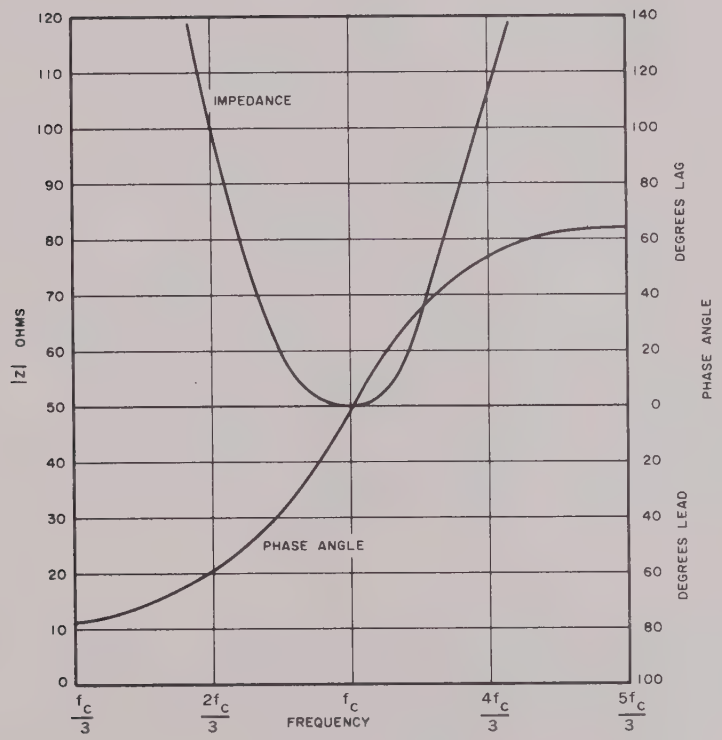

FIGURE 3. TYPICAL IMPEDANCE CHARACTERISTICS OF AILTECH 32 PRECISION ATTENUATOR

SECTION IV
THEORY OF OPERATION

A. INCREMENTAL ATTENUATION

The incremental attenuation of the AILTECH 32 precision attenuator is provided by varying the distance between coplanar radiating and receiving coils in a circular waveguide operated below its cutoff frequency. Since the cutoff frequency is about 13.8 GHz, there is no true wave propagation at the operating frequency. The TE_{11} mode which couples the two coils in this configuration has the lowest possible rate of attenuation and any inaccuracies caused by the presence of other modes are minimized. The field for any single mode is attenuated exponentially along the axis of the waveguide, making the change in attenuation in decibels a linear function of the separation of the coils.

Two possible sources of error in a piston attenuator of this type are the proximity of the operating frequency to the cutoff frequency, and the effective depth of RF current penetration into the walls of the waveguide. The following formulas

show the effect of these two quantities on the attenuation constant.

$$a = 31.98 \left[1 - \frac{d}{D} - \frac{1}{2} \left(\frac{f}{f_c} \right)^2 \right] \qquad (1)$$

$$d = (\pi f \mu \sigma)^{-1/2} \qquad (2)$$

$$f_c = \frac{3(10^8)}{1.71\ D} \qquad (3)$$

where

a - attenuation (dB per diameter),

D = diameter of waveguide (meters),

d = depth of penetration (meters),

f = operating frequency (Hertz),

f_c = cutoff frequency of TE_{11} mode (Hertz),

μ = permeability of space ($4\pi\ 10^{-7}$ henry per meter),

σ = conductivity (mhos per meter).

Combining and simplifying these equations, the attenuation constant for this attenuator in dB per inch is found to be:

$$a = 64.059\ (1 - 5.06f^{-1/2} - 0.259f^2 10^{-20}) \qquad (4)$$

For any single waveguide diameter, the useful range of the attenuator is limited by the depth of penetration at low frequencies and the proximity to the cutoff frequency at the higher operating frequencies. The attenuation, A, is relatively constant over a wide frequency range.

B. MINIMUM INSERTION LOSS

The minimum insertion loss is determined by the design of the coils and the minimum spacing between the coils. These coils are designed to minimize the excitation of higher order modes which would cause attenuation errors. Since the attenuation rates of the higher order modes are higher than that of the fundamental mode, the linearity and accuracy improves as the spacing between the coils is increased. The minimum insertion loss is chosen to avoid the inaccuracies which occur at smaller spacings.

C. IMPEDANCE CHARACTERISTICS

The input and output circuits are tuned to present a 50-ohm resistive impedance at the desired operating frequency. As shown in Figure 4, the inductance of the coil is tuned with a series capacitor. The curves shown in Figure 3 show typical data on the magnitude and phase of the impedance presented at the input or output connectors of AILTECH 32 attenuators.

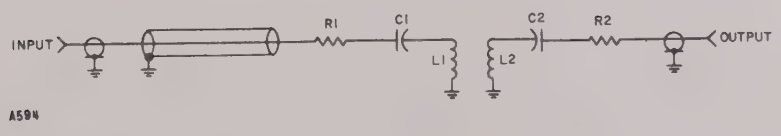

FIGURE 4. SCHEMATIC DIAGRAM OF AILTECH 32 PRECISION ATTENUATOR

D. PHASE CHARACTERISTICS

The phase relationship between the input and output voltages is dependent upon the attenuator setting. The phase shift is caused by the resistivity of the cylinder walls. The phase shift sensitivity has been shown to be a constant* at any fixed frequency; for this attenuator it is equal to:

$$\phi = \frac{2.73}{\sqrt{f}} \qquad (5)$$

where

ϕ = phase change (degrees per 10 dB),

f = frequency (MHz)

At 30 and 60 MHz these corrections are respectively 0.05 and 0.035 degree per 10 dB change in attenuation.

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* J. Brown, "Corrections to the Attenuation Constants of Piston Attenuators," Proc IEE, Vol 96, part 3, p 491-495, November 1949.

SECTION V
MAINTENANCE

A. SERVICING

Servicing of the attenuator is limited to oiling the piston every six months. Crank the piston about 1/2 inch out from the fully seated position and apply one drop of light instrument oil to the piston near the bearing. Crank the piston in and out to distribute the oil.

CAUTION

Do not apply more than one drop of oil to the piston. Oil inside the piston sleeve can cause electrical malfunction.

B. REPAIR OF UNIT

Do not attempt to disassemble the unit or make gear train adjustments. The attenuator should be returned to the factory for any repairs.

Prior to returning the equipment for repair, please write to AILTECH, West Coast Operation, giving the type and serial number of the unit, complete information concerning the nature of the failure, and the manner in which the equipment was

used when failure occurred. Special instructions will be supplied to the customer for shipping the unit back for repairs. All equipment should be packed and shipped in accordance with these instructions with transportation charges prepaid. Sufficient packaging material should be used so that in-transit damage is avoided. A failure report should accompany shipment of the equipment.